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Abstract

Many central banks actively intervene in the foreign exchange (forex) market, although there is no consensus on its impact on the exchange rate level and volatility. We analyze the effects of daily forex interventions in four Latin American countries with inflation targets —namely, Chile, Colombia, Mexico and Peru—by fitting GARCH-type models. These countries represent a broad span of intervention strategies in terms of size and frequency, ranging from pure discretionality to intervention rules. We also provide new evidence on the presence of asymmetries, which arise if foreign currency purchases and sales have different effects on the exchange rate. We find that first interventions, either isolated or initial in a rule, reduce exchange rate volatility, although their size plays a minor role. Our results support the signaling effect of interventions under inflation targeting regimes.

Keywords: Exchange rate volatility; Foreign exchange interventions; GARCH.

JEL classification: F31; G15; C54.

Resumen

Pese a que no existe un consenso sobre el impacto de las intervenciones cambiarias en el tipo de cambio y en su volatilidad, numerosos bancos centrales intervienen activamente en estos mercados. En este trabajo se analizan los efectos de las intervenciones cambiarias diarias de cuatro países de América Latina —en concreto, Chile, Colombia, México y Perú—, mediante modelos de la familia de los GARCH. Estas economías representan una amplia gama de estrategias de intervención en términos de tamaño y frecuencia, ya que comprenden de la pura discrecionalidad a la adopción de reglas cambiarias automáticas. También se analiza la presencia de asimetrías que surgen si las compras y las ventas de moneda extranjera tienen un impacto diferente en el tipo de cambio. En este trabajo se concluye que las primeras intervenciones, bien sean aisladas, o bien las primeras de una regla, tienen un efecto moderador en la volatilidad cambiaria, mientras que el tamaño de la intervención desempeña un papel menor. Nuestros resultados sugieren un «efecto señalización» de las intervenciones en economías con objetivos de inflación.

Palabras clave: volatilidad cambiaria, intervenciones cambiarias, modelos GARCH.

Códigos JEL: F31; G15; C54.

1 Introduction

Foreign exchange (forex) interventions are sales or purchases of foreign assets (typically US dollars —USD hereafter—, but also other major currencies) aimed at impacting on the level and/or volatility of the exchange rate. If a central bank considers that the exchange rate has deviated excessively from its equilibrium, it would sell (buy) local currency during periods of appreciatory (depreciatory) pressures.

Empirical evidence shows that central banks frequently perform this type of interventions, regardless of their monetary policy scheme (Stone et al., 2009). Implicitly, monetary authorities support the idea that forex interventions are useful to manage the exchange rate level and volatility.[1] Given the policy implications of their effectiveness, a large empirical literature has flourished but the evidence is still mixed. In particular, the papers that analyze daily exchange rates, which is the most employed time frequency, provide three main views. First, most works conclude that interventions do not alter the exchange rate level and they can even increase the exchange rate volatility. See, for instance, Baillie and Osterberg (1997), Dominguez (1998) or Edison et al. (2006). This conclusion suggests that interventions might introduce market uncertainty. However, this could be the result of a simultaneity problem of daily data as intervention dates probably coincide with the response of central banks to an exchange rate volatility excess, so that both variables would be positively correlated. Thus, concluding that higher volatility is a result of interventions could be misleading (Kim et al., 2000). Endogeneity also lies behind some counterintuitive results regarding the effects on the exchange rate level which are consistent with 'leaning against the wind' strategies with, for instance, USD purchases appreciating the local currency (Baillie and Osterberg, 1997).

On a more positive tone, other authors state that forex interventions can influence on the exchange rate level and 'calm disorderly markets', thereby moderating the exchange rate volatility (Kim and Pham, 2006; Hoshikawa, 2008).[2] Finally, the most skeptical

[1]For instance, according to the surveys by Neely (2000; 2008), central banks disagree with the assertion that intervention increases volatility.

[2]These authors find that high frequency forex interventions of the Reserve Bank of Australia and the Bank of Japan, respectively, were effective to reduce the exchange rate volatility, whereas low frequency and officially announced interventions mainly affected the exchange rate level.

view states that forex interventions have a negligible impact on the currency level and volatility, as shown by Dominguez (2006) for the G3.[3]

As reported in Adler and Tovar (2011), relatively few central banks publish their daily forex interventions, which justifies that most of this literature is focused on country specific analysis. Most papers analyze the G3 and Australia,[4] whereas the literature is much more scarce for emerging economies (EMEs hereafter) as authorities are more reluctant to provide official data on their operations. Although transparency is improving, at present only a reduced number of countries—mainly from Latin America— release daily information, which have led to a few empirical papers. For instance, Humala and Rodriguez (2010) and Kamil (2008) analyze Peru and Colombia, respectively, whereas Domaç and Mendoza (2004) focus on Mexico and Peru. Forex interventions in EMEs have a different nature than in developed countries, so that, in principle, their effects could differ. In particular, EMEs tend to intervene more frequently in the forex markets than the developed ones, independently of their monetary policy regime (Berganza and Broto, 2012). Besides, a priori, it seems sensible that forex interventions in EMEs might be more effective than in developed countries (Disyatat and Galati, 2007).[5] However, the evidence for EMEs is not conclusive either. For instance, Disyatat and Galati (2007) find that interventions had no influence on the short-term volatility of the Czech koruna, whereas Domaç and Mendoza (2004) find the opposite result for Mexico and Turkey.

Another relevant aspect regarding forex interventions is their wide spectrum of characteristics in terms of frequency and size. For instance, in most developed countries such as Japan, the current policy is to intervene on a discretionary basis and only under exceptional circumstances, whereas in EMEs intervention strategies differ across countries

[3]This author analyzes intra-daily and daily exchange rates of the G3 and concludes that interventions can influence exchange rates only within the day.

[4]See, for instance, Rogers and Siklos (2003), Kim and Sheen (2002), Edison et al. (2006), Kim and Pham (2006) for some empirical papers on Australia; Baillie and Osterberg (1997) and Dominguez (1998) for the G3, and Frenkel et al. (2005), Watanabe and Harada (2006), Kim and Sheen (2006), Hillebrand and Schnabl (2008) or Hoshikawa (2008) for Japan.

[5]According to these authors, this is due to: (i) the larger size of forex interventions relative to market turnover in EMEs; (ii) the greater leverage of central banks in the case of existence of some form of capital controls; (iii) the informational advantage that represents their lower level of sophistication.

and run from fully discretionary interventions (Brazil, Peru) to intervention rules (Chile). Introducing these features in the model specification could help to obtain additional information on the effect of interventions (Kim and Pham, 2006).

Besides, in this literature, the presence of asymmetries has not been much analyzed yet (Baillie and Osterberg 1997, Domaç and Mendoza, 2004 or Guimarães and Karacadag, 2004). Forex interventions will have an asymmetric effect if sales of foreign currency (negative interventions) have a different impact on the exchange rate volatility than that of purchases (positive interventions). After the onset of the crisis, many central banks performed interventions of opposite sign than those of the previous period (BIS, 2010), which has allowed to increase the number of observations for the study of asymmetries.

The main objective of this paper is to analyze the efficiency of forex interventions to influence on the exchange rate level and volatility of four Latin American countries with inflation targets—namely, Chile, Colombia, Mexico and Peru—. We focus on the possible asymmetric effects of interventions, as well as their size and frequency. To that purpose, we carry out a time series analysis for their daily bilateral exchange rates against the USD, by fitting a battery of univariate GARCH type models. This type of model has been broadly used in this literature since Baillie and Osterberg (1997) or Dominguez (1998). Although GARCH models entail the aforementioned simultaneity problems, this is a sensible procedure to deal with daily data.[6] As far as we know, this is the empirical paper that studies the efficiency of daily interventions for a greater number of Latin American countries with an homogeneous model. Our results suggest that first interventions, either isolated or initial in a rule, reduce the volatility, whereas their size plays a minor role.

The paper is organized as follows. After the introduction, Section 2 briefly describes the main transmission channels of sterilized interventions on the exchange rate. Then, Section 3 describes the data set, which consists of the daily exchange rate returns and forex

[6] A GARCH type model is not the unique empirical approach proposed in this literature to analyze the link between forex interventions and exchange rates. For instance, Neely (2008) summarizes the main methodologies with particular emphasis in structural type models that simultaneously fit both variables.

interventions of our four countries. Then, Section 3 presents the GARCH models that will be used to analyze the impact of interventions on the exchange rate level and volatility distinguishing the presence of asymmetries, as well as intervention characteristics such as size and frequency. In Section 4, we report the main empirical findings. Finally, Section 5 concludes.

2 Transmission channels of forex interventions

Currently almost all countries, including our four Latin American economies, sterilize their interventions through open market operations that eliminate their effect in the domestic money supply. Thus, whereas non sterilized interventions immediately impact on exchange rates through the monetary channel, sterilized intervention do not influence on the exchange rate directly through the usual monetary mechanisms, but though indirect channels. The lack of consensus in the empirical literature regarding the effectiveness of forex interventions is precisely rooted on the indirect character of the transmission channels of sterilized interventions. There are three main theoretical explanations for intervention effectiveness that have been mostly studied from a theoretical point of view, namely the signaling, the portfolio-balance and the international coordination channel (Sarno and Taylor, 2001).

The signaling channel was first described in Mussa (1981). Forex interventions affect the exchange rates through this mechanism when the central banks intervene to signal their future monetary policy or the long-run equilibrium to the markets. Thus, when market participants revise their expectations on these fundamentals, they simultaneously adjust their prospects on future spot exchange rates, which has an impact on the current exchange rate. That is, the information that the central bank provides through interventions may lead investors modify to the exchange rate.[7] In most signaling models there is the implicit hypothesis that intervention signals are fully credible an unambiguous (Dominguez, 1998).

On the other hand, in portfolio-balance exchange rate models investors diversify their holdings among domestic and foreign currencies denominated bonds. As both assets are imperfect substitutes, an sterilized intervention may induce investors to trade currencies

[7] Dominguez (1990) discuss the possible credibility games that implies the signaling channel.

to maintain their share of domestic and foreign assets, which will probably result in a change in the exchange rate. Finally, Sarno and Taylor (2001) or Reitz and Taylor (2006) also mention the international coordination channel, where interventions play a role in the coordination of expectations by rational speculators.

Previous empirical studies are inconclusive with respect to the validity of these transmission mechanisms of sterilized interventions (Edison, 1993). Nevertheless, as reported in different surveys performed to policymakers, central bankers tend to believe in the efficacy of the signaling and the coordination channel, whereas the portfolio-balance channel hypothesis is not taken much into consideration (Lecourt and Raymond, 2006; Neely, 2008). See, for instance, Sarno and Taylor (2001) or Neely (2008), for further details on the three transmission channels.

3 The data

We study the impact of interventions on the exchange rate level and volatility of four currencies. In particular, we analyze the daily returns of the USD vis-à-vis the Chilean peso (CLP), the Colombian peso (COP), the Mexican peso (MXN) and the Peruvian nuevo sol (PEN). That is, an increase (decrease) of the nominal bilateral exchange rate is an appreciation (depreciation) of the local currency against the USD.[8] Daily forex interventions were obtained from national sources.[9] We only consider sales and purchases of USD, as this is the most widely used currency to implement interventions in all countries. See Appendix A for some description and data sources of forex intervention.[10]

Figure 1 represents the four currency pairs and the daily forex interventions (net forex purchases or sales), where positive interventions indicate USD purchases and negative values are official USD sales. In the years preceding the crisis, forex interventions in

[8]We have obtained all currency pairs from Datastream.

[9]Nowadays there is no comprehensive and updated database on daily forex interventions. Up to our knowledge, the Federal Reserve Bank of Sant Louis provides the best data compilation, but it is particularly focused on developed countries (http://research.stlouisfed.org/fred2/categories/32145).

[10]Forex interventions should be distinguished from those operations of central banks in the forex market to manage official reserves or to meet transaction needs of the government (Chiu, 2003). Note that with our database it is not possible to distinguish between both objectives.

Chile, Colombia and Peru were more targeted to foreign exchange purchases rather than sales, which reflects their appreciating trend in their role of commodity linked and high yield currencies. On the contrary, the accumulation of reserves in Mexico prompted the authorities to sell USD from 2003 (Guimarães and Karacadag, 2004). After the onset of the crisis in 2008 all countries suffered depreciatory pressures and sold dollars.

As shown in Figure 1, the four countries represent a variety of intervention strategies. Whereas in Peru the current policy is to intervene on a discretionary basis under exceptional circumstances the intervention strategy in Chile and Colombia is based on rules, which imply more frequent and relatively smaller interventions. There are two types of rules: Exchange rate-based rules, normally aimed at moderating the exchange rate volatility (Colombia), or quantity-based rules aimed at the accumulation of reserves (Chile). Since February 2010 Mexico also holds this latter type of rule (Adler and Tovar, 2011). According to Frankel and Dominguez (1993) interventions have a maximum impact when they occur unexpectedly, which would support the effectiveness of isolated interventions, but other authors conclude that the series of interventions might be perceived as more credible to market participants (Kim et al., 2000).

Apart from representing a wide range of intervention strategies, we have chosen these four currency pairs for other reasons. First and more importantly, their daily forex interventions are publicly available.[11] Indeed, our country sample represents all the economies that publish daily data, as reported in Adler and Tovar (2011), that meet certain prerequisites. First, we explicitly exclude those countries that have not performed interventions to influence on their own currencies after the onset of the last crisis, although they publish daily releases. This is the case of Canada, United Kingdom, the United States or Turkey.[12] Besides, their sample sizes should also be large enough for a GARCH type analysis.[13] For instance, we do not analyze Israel as the central bank has only intervened

[11] Data scarcity might justify the use of reserve variations as a proxy for intervention. However, daily reserve variations are a bad approximation of forex interventions (Adler and Tovar, 2011).

[12] That is, coordinated interventions performed to modify the exchange rate of a different country are not considered. Thus, the last forex intervention by Bank of Canada, the Federal Reserve and the Bank of England was in March 2011 but it was a coordinated action to stabilize the JPY and not a direct measure to stabilize its own currency. Finally, most recent intervention in Turkey was in 2006.

[13] For instance, if the sample of forex interventions is very small, their impact could be mislead with that of an additive outlier, which can affect the identification of conditional heteroscedasticity and the estimation of GARCH type models (Carnero et al., 2007).

three times after 1997 (Sorezcky, 2010). Finally, we do not consider Australia as interventions are published with a one year lag. All in all, we end up with a representative sample of Latin American countries, where our four economies are among the seven largest in the region in terms of GDP based on PPP valuation.[14]

Table 1 reports the exchange rate regime and monetary policy arrangement of the four countries, which can influence the impact of interventions (Disyatat, 2007). According to IMF's classification, all countries but Colombia and Peru, which follow a managed floating regime with no pre-determined path for the exchange rate, have floating currencies and all countries follow an inflation target. Note that even though the four EMEs have adopted inflation targets during the last years, so that in theory the exchange rate plays no role as nominal anchor, these economies intervene actively in the forex markets (Berganza and Broto, 2012).[15] The sample period varies across countries and runs from 31/7/1996 to 6/6/2011 for the USD/MXN ($T = 3873$) to 1/1/2004 to 15/6/2011 in the case of the CLP ($T = 1944$). The beginning of the sample period indicates the first official publication date of forex interventions.

Table 1 also shows some descriptive statistics for total interventions, I_t, as well as for negative and positive interventions, denoted as I_t^- and I_t^+, respectively. Note that negative interventions, I_t^-, indicate sales of USD and are typically performed under depreciatory pressures, while I_t^+ stand for USD purchases, which are characteristic of periods of appreciatory pressures of the local currency. Whereas the central bank of Colombia has intervened around 19% of the trading days during the sample period, the Central Reserve Bank of Peru intervened around 61% of the days. In general, net sales of USD are much less frequent than net purchases. For instance, they represent 7% of total interventions in Colombia, whereas Mexico is the only country where negative interventions are more frequent than positive ones (89%).

[14]According to the World Economic Outlook Database of the IMF (September 2011).

[15]Whereas Chile and Colombia adopted and inflation target in 1999, Mexico introduced this monetary policy framework in 2001 and Peru in 2002 (IMF, 2005).

Table 2 reports some descriptive statistics for the four exchange rate returns, r_t, for total interventions, I_t, and for I_t^+ and I_t^-. All these series are asymmetric and have excess kurtosis. The skewness of all exchange rate returns is negative. That is, extreme values of returns are related to currency depreciation. Box-Pierce Q-statistics for higher order serial correlation reveal that squared returns are much more autocorrelated than non-squared data, which implies the presence of conditional heteroscedasticity in all exchange rate returns and evidences the suitability of a GARCH type model in this setting. Regarding forex interventions, as illustrated in Table 2, in Colombia the average absolute value of negative interventions is larger than that of positive interventions, whereas in Mexico the opposite holds. In Chile, positive and negative interventions have a similar volume, which is inherent to the design of its intervention rule. Besides, I_t^+ and I_t^- are also asymmetric and have excess kurtosis,[16] where the absolute value of the skewness coefficient of I_t^- is larger than that of I_t^+ in Mexico and Chile. That is, extreme events of the distribution of interventions tend to be associated with USD sales.

4 Empirical model

We model the percent returns of the nominal exchange rate of the USD against the four currencies, which are represented in Figure 2 and are given by,

$$r_t = 100 \times (\Delta \log E_t) \tag{1}$$

where E_t is the bilateral nominal exchange rate in t and Δ is the difference operator so that a positive r_t denotes a local currency appreciation against the USD.[17]

Our baseline model is a simplified version of that proposed by Dominguez (1998) to analyze forex interventions and exchange rate volatility in the G3, which follows this expression,

$$r_t = \beta_0 + \beta_1 r_{t-1} + \beta_2 I_{t-1} + \varepsilon_t \tag{2}$$

$$\varepsilon_t = \varepsilon_t^{\dagger} h_t^{1/2} \tag{3}$$

$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 h_{t-1} + \gamma_1 |I_{t-1}| \tag{4}$$

[16]Note that these statistics cannot be calculated for I_t^+ in Chile, as it is constant for the whole period.
[17]We subtract the mean of $\Delta \log E_t$ to guarantee zero mean returns (Harvey et al., 1994).

where, $\forall t = 1, ..., T$, r_t are the daily exchange rate returns, $|I_{t-1}|$ is the absolute value of lagged forex interventions and $\varepsilon_t^{\dagger}$ is a Gaussian white noise process. As Dominguez (1998) or Hoshikawa (2008), we introduce interventions in the mean and in the conditional variance, where $|I_{t-1}|$ should appear in absolute value to guarantee its positivity. In (2) we also add r_{t-1} for pre-whitening purposes, as usual in the empirical finance literature. For the sake of simplicity, we omit any additional explanatory variables in the model.[18]

Note that forex interventions are lagged to circumvent simultaneous bias, in line with Baillie and Osternberg (1997), among others. Thus, as r_t is the return on the exchange rate between the closing day $(t-1)$ and t, interventions in $(t-1)$, I_{t-1}, which occur during the business operating hours (Neely, 2000), are predetermined. As mentioned, all methodologies in this literature, have to deal with the simultaneity between the interventions and the exchange rate returns. This fact constitutes an endogeneity issue inherent to this problem. Indeed, assuming that interventions are exogenous to market conditions would be rather strong taking into account that monetary authorities explicitly declare that they intervene to calm disorderly markets (Dominguez, 1998; Kim and Sheen, 2002; Frenkel et al., 2005). As noted by Kim and Pham (2006) one possible solution to this problem lies precisely in the own data selection by lagging interventions, as we propose. Another alternative would be to use high-frequency intra daily data, but the specific time of intervention is not available.[19]

A negative (positive) coefficient of the interventions in (2), β_2, will indicate that a net purchase of foreign currency is followed by a depreciation (appreciation) of the local currency. Note that a positive estimate of β_2 could imply that interventions have not influenced r_t in the desired way, as USD purchases would be associated with a local currency appreciation. However, this outcome is consistent with a 'leaning against the

[18]Some authors such as Dominguez (1998) use interest rate spreads to control for the monetary policy stance. Our preliminary results including interest rate differentials do not vary significantly, so that in line with Edison et al. (2006), Beine et al. (2009) or Hoshikawa (2008) we do not consider this variable. In the mean equation we do not consider either day of the week and holiday dummy variables for simplicity. These last variables would lead to degenerated likelihood surfaces if they are included in the conditional variance (Doornik and Ooms, 2003).

[19]See Kim and Pham (2006) for further analysis on endogeneity in this literature.

wind' strategy, which is also linked with the aforementioned endogeneity issues, as the central bank buys dollars as a response to the appreciatory pressures on their currency. In this sense, forex interventions are helping to moderate the previous exchange rate trend.[20] On the other hand, the estimates of γ_1 in (4) would be negative if the exchange rate volatility moderates after the forex intervention.[21]

We also estimate a modified version of this baseline model modifying the conditional variance (4) to incorporate asymmetries.[22] This allows us to analyze if interventions to stabilize the currency under depreciatory or appreciatory pressures have a different impact on the exchange rate volatility. For this purpose we substitute the conditional variance in (4) with this expression,

$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 h_{t-1} + \gamma_2 \left| I_{t-1}^- \right| + \gamma_3 I_{t-1}^+, \tag{5}$$

where $\left| I_t^- \right|$ and I_t^+ stand for $|I_t|$. The effect of negative interventions on the exchange rate returns is γ_2 whereas that of positive interventions is γ_3. This conditional variance equation in (5) also allows to perform Wald-type tests for the null that interventions have a symmetric effect on the conditional variance, $H_0 : \gamma_2 = \gamma_3$.

In a third stage we analyze if considering some characteristics of forex interventions is useful to disentangle their link with the exchange rate volatility. With this purpose we use the following specification,

$$\begin{aligned} r_t &= \beta_0 + \beta_1 r_{t-1} + (\beta_2 + \beta_3 FIRST_{t-1} + \beta_4 SIZE_{t-1}) I_{t-1} + \varepsilon_t & (6) \\ \varepsilon_t &= \varepsilon_t^{\dagger} h_t^{1/2} & (7) \\ h_t &= \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 h_{t-1} + (\gamma_1 + \gamma_4 FIRST_{t-1} + \gamma_5 SIZE_{t-1}) \left| I_{t-1} \right| & (8) \end{aligned}$$

[20] Humpage (2000) denotes this forex intervention objective as the smoothing criterion, as it is based on smoothing previous trend.

[21] In the estimation process we have imposed positivity constraints on h_t to avoid negative variances resulting from these negative coefficients.

[22] We do not consider asymmetries in the mean equation to distinguish the effect of positive and negative forex interventions in the exchange rate returns. Our preliminary exercises, which are available upon request, show that this asymmetry is hardly significant in our data.

where $FIRST_t$ is a dummy variable that is one if I_t is the first intervention in a series or an isolated intervention, that is, if $I_{t-1} = 0$ and $I_t \neq 0$, and zero otherwise.[23] As in Kim and Shenn (2006) and Kim and Pham (2006), $SIZE_t$ is a dummy variable that is one if the absolute value of I_t is greater than the average daily absolute interventions. Note that $FIRST_t$ and $SIZE_t$ can be highly correlated, as isolated interventions use to be bigger than consecutive interventions.[24]

Finally, we perform some statistical inference on the presence of asymmetries in the conditional variance equation (8) by also considering this alternative specification,

$$\begin{aligned} h_t &= \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 h_{t-1} + \\ &\quad (\gamma_2 + \gamma_6 FIRST_{t-1} + \gamma_7 SIZE_{t-1}) \left| I_{t-1}^- \right| + (\gamma_3 + \gamma_8 FIRST_{t-1} + \gamma_9 SIZE_{t-1}) I_{t-1}^+, \end{aligned} \tag{9}$$

which also allows to test for the presence of asymmetries depending on the size and the systematic character of interventions. For instance, a test of the null hypothesis that large and first interventions, either isolated or first in a row, are symmetric is $H_0 : \gamma_2 + \gamma_6 + \gamma_7 = \gamma_3 + \gamma_8 + \gamma_9$.

5 Main results

5.1 Baseline model

Table 3 reports the estimates of the baseline model in equations from (2) to (4) for the USD against the four currencies.

Regarding the level equation, the estimated coefficient of the forex interventions, $\hat{\beta}_2$, is only significant for Colombia and it is positive, which indicates that USD purchases by the Colombian central bank are related to an appreciation of the COP. The most feasible interpretation of this positive sign for $\hat{\beta}_2$, as highlighted by Edison et al. (2006) for Australia, is that these interventions are consistent with a 'leaning against the wind' behavior, in that its net purchases (sales) of foreign assets coincided with an appreciation

[23] In a complementary way, Kim and Sheen (2006) have analyzed intervention effectiveness if they persist over a number of days.

[24] The correlation between $FIRST_t$ and $SIZE_t$ in our sample run from 0.01 in Peru to 0.64 in Colombia.

(depreciation) of the local currencies so that both variables are positively correlated. The fact that $\hat{\beta}_2$ is not significant for Chile, Mexico and Peru evidences certain lack of success of forex interventions to alter the exchange rate.[25] Finally, as expected, $\hat{\beta}_1$ is significant but small or not significant.

As reported in Table 3, the GARCH estimates $\hat{\alpha}_0$, $\hat{\alpha}_1$ and $\hat{\alpha}_2$ of the conditional variance equation in (4) are positive and significant. As usual in empirical applications, $(\hat{\alpha}_1 + \hat{\alpha}_2)$, which approximates volatility persistence, is close to unity. This indicates that once volatility is high, the exchange rate volatility remains high for a long period. The estimates of the absolute value of interventions, $\hat{\gamma}_1$, exhibit a variety of results. On the one hand, they are positive and significant for Chile and Colombia, so that forex interventions would be associated with even greater exchange rate volatility, in line with Edison et al. (2006). This positive sign indicates that in the periods of forex interventions (either USD purchases or sales) the exchange rate volatility increases. The interpretation of this sign can be ambiguous rooted on the already mentioned causality issues. Again, one possible interpretation is that forex interventions add uncertainty to the market but, on the other hand, it can be interpreted that forex interventions simply coincide with periods of higher uncertainty, which is precisely the reason to intervene. On the other hand, $\hat{\gamma}_1$ is negative and significant for Peru, meaning that interventions are linked to a lower contemporaneous volatility, and not significant for Mexico. Finally, in general Box-Pierce statistics for high-order serial correlation of the squared standardized residuals in Table 3 support the role of these GARCH models to capture the dynamics of the exchange rate conditional variance.[26]

Nevertheless, as intervention policy changes throughout time, the impact of interventions on the exchange rate could have varied during the sample period as well, as

[25] Following the classification of Humpage (2000), there are two criteria to characterize the success of a forex intervention: the direction criterion and the smoothing criterion. The direction criterion would fulfill if interventions manage to change the exchange rate direction (for instance, USD purchases depreciate de local currency), which would lead to a positive $\hat{\beta}_2$. On the other hand, the smoothing criterion seeks to moderate the current currency trend. This would be in line with the 'leaning against the wind' behavior and would be linked with a positive $\hat{\beta}_2$.

[26] Note that $Q(20)$ in Table 3 is still significant for all countries but Mexico, whereas $Q^2(20)$ for Peru still indicates the presence of certain dynamics in the conditional variance. This outcome is a consequence of fitting a unique model for all countries. However, these Ljung-Box Q-statistic will become non significant in some of the following model specifications.

illustrated in Figure 3. This figure shows the t-statistics of $\hat{\gamma}_1$ for the four countries obtained with a rolling window of 1500 observations for Colombia, Mexico and Peru and 750 for Chile. As shown by these statistics, whereas in Chile interventions tend to have a moderating effect on volatility, the opposite holds for Colombia. In Mexico and Peru $\hat{\gamma}_1$ helped to moderate volatility at certain subperiods previous to the onset of the crisis.[27]

All in all, the estimates for the baseline model could seem rather ambiguous regarding the effect of forex interventions on the exchange rate level and volatility. In the next subsections the introduction of asymmetries and intervention characteristics in the model specifications will allow to disentangle further conclusions.

5.2 Capturing asymmetric effects in the conditional variance

In Table 4 we model asymmetric effects in the conditional variance to differentiate USD sales from purchases through the estimates of $\hat{\gamma}_2$ and $\hat{\gamma}_3$, respectively, in (5). Indeed, once we fit the model we perform Wald type test for the null $H_0 : \gamma_2 = \gamma_3$ to distinguish if positive and negative interventions have a significantly different impact on the conditional variances. We reject this hypothesis for Colombia, Mexico and Peru, whereas for Chile we cannot reject the null of symmetry. This result constitutes a first evidence of the importance of fitting asymmetries in this setting. On the other hand, the symmetric impact identified for the Chilean interventions seems a rather sensible result given their intervention rule scheme based on preannounced purchases or sales of USD of the same magnitude.

As reported in Table 4, in Chile the effects of interventions on the conditional volatility are mainly driven by USD sales (negative interventions), where $\hat{\gamma}_2$ has a positive sign. On the contrary, in Colombia the positive interventions (USD purchases) dominate the total effect of interventions leading to higher volatility. However, negative interventions (USD sales) do stabilize the COP, as indicated by the negative $\hat{\gamma}_3$, although the effect of

[27] In the remaining subsections we do not show the estimates of the rolling regressions due to identification problems for some countries. Thus, if a country has not performed interventions of a certain sign or $FIRST_t = 0$ or $SIZE_t = 0$ for a prolonged period the model cannot be estimated. The complete battery of figures for the rolling regressions are available upon request.

positive interventions seem to prevail. In Mexico and Peru both USD purchases and sales do moderate the exchange rate volatility. Thus, after fitting the asymmetric conditional variance, both positive and negative interventions are associated with lower exchange rate volatility, which is contrary to Guimarães and Karacadag (2004) and Domaç and Mendoza (2004) for Mexico.[28] In both countries USD purchases have a slightly higher effect than that of sales (in absolute value).

5.3 The role of forex intervention characteristics

Table 5 reports the estimates for the model in equations from (6) to (8), which incorporate the variables $FIRST_t$ and $SIZE_t$ to analyze if the characteristics of forex interventions do affect the exchange rate level and volatility. In Mexico first and sizeable interventions would be consistent with a 'leaning against the wind' role of the central bank, which is also the case of the first interventions of the Chilean rule—as evidenced by the positive and significant $\hat{\beta}_3$ and $\hat{\beta}_4$—. These results are in line with previous works for developed countries.[29] On the contrary, the lack of significance of $\hat{\beta}_3$ and $\hat{\beta}_4$ in Colombia and Peru indicates that it is not relevant to consider $FIRST_t$ and $SIZE_t$ in their level equation.

The estimates of the conditional variance in (8) also highlight the importance of including $FIRST_t$ and $SIZE_t$ in the estimation process. For instance, first interventions lead to a lower conditional variance of the Mexican and Colombian peso, whereas in Peru the negative $\hat{\gamma}_1$ and the positive $\hat{\gamma}_5$ indicate that small and "not first" interventions are followed by lower conditional variances.

Finally, Table 6 reports the conditional variance estimates of (10), where previous model is augmented distinguishing a different effect of positive and negative interventions.

[28] Guimarães and Karacadag (2004) conclude that USD sales have an small impact on the USD/MXN level, which would be in line with our results, and that these negative interventions increase its volatility. Domaç and Mendoza (2004) also identity a moderating effect of USD sales, but not for the purchases. These divergences with our outcomes can be rooted on their different treatment of endogeneity, their model specification and their sample period.

[29] For instance, Kim et al. (2000) and Kim and Pham (2006) conclude that large interventions in Australia have been effective in controlling the exchange rate level, whereas Hoshikawa (2008) conclude that low frequency and officially announced interventions in Japan mainly affect the exchange rate level.

In line with our previous results, Wald type tests for different null hypothesis show that introducing asymmetries is relevant to improve the model specification as the null of symmetry is rejected in all countries but Chile. Thus, modeling asymmetries and intervention characteristics seems useful to disentangle further conclusions.

For instance, in Mexico, not all first interventions are helpful to lower the conditional variance. Indeed, only negative first interventions play this moderating role, as shown by the estimates of γ_6. Note that the size of USD sales is related to higher exchange rate volatility, whereas small negative interventions, either first or not, do have an effect while representing 83% of total interventions. Of these USD sales, first interventions were mostly preannounced, so that this result might hint at the signaling role of these interventions throughout the sample period, which supports the stabilizing function of intervention rules in Mexico. Our result would be contrary to Guimarães and Karacadag (2004), who stated that negative interventions increase the MXN short term volatility.[30] Finally, positive interventions in Mexico were mostly performed to accumulate foreign reserves and not as a tool to directly influence on the exchange rate, which could explain the lack of significance of the coefficients for positive interventions, I_t^+.

This signaling effect of interventions seems to be also the case of the Chilean peso, where first and positive interventions lead to lower exchange rate volatility, as evidenced by the negative and significant $\hat{\gamma}_8$. That is, once the intervention rule to buy USD is announced by the authorities, it has an immediate effect on the volatility, this initial impact vanishes in the subsequent interventions, as shown by the lack of significance of $\hat{\gamma}_3$. The significance of first interventions emphasizes the success of transparency and public announcements to moderate volatility, although these effects seem to have a short term impact that coincides with the announcement of the intervention rule.

In Colombia first interventions are also relevant, but in this case both USD purchases and sales do moderate COP volatility, as shown by the negative and significant $\hat{\gamma}_6$ and $\hat{\gamma}_8$.[31] Colombia is the only country of our sample where the intervention size does help to moderate the exchange rate volatility, but only for sizeable USD sales, as indicated

[30]Our result is in line with Domaç and Mendoza (2004), although they did not characterized size and frequency of interventions.

[31]In Colombia, first interventions correspond to 19% of total interventions.

by $\hat{\gamma}_7$. In Peru, that currently intervenes in a discretionary way, first interventions also curb volatility, but only USD purchases, as shown by the estimate for γ_8. Finally, small negative interventions, which characterize 33% of interventions, are also associated with lower exchange rate volatility, as $\hat{\gamma}_2$ evidences.

All in all, although apparently it seems difficult to infer empirical regularities across the four countries, there is certain homogeneity regarding those intervention characteristics that matter to diminish volatility. For instance, in the four economies first interventions, either positive or negative, play a role to curb the conditional variance. That is, the estimates for $FIRST_t$, either $\hat{\gamma}_6$ and/or $\hat{\gamma}_8$, are significant and negative in the four countries. This moderating effect of first intervention is independent of the exchange rate regime, as these economies have either recently implemented an intervention rule—namely, Chile, Colombia and Mexico—, either exchange rate-based or quantity based, or intervene in a discretionary way. On the other hand, the intervention size seems to be less relevant to calm volatility, as the estimates for $SIZE_t$, ($\hat{\gamma}_7$ or $\hat{\gamma}_9$), are not significant or positive for almost any country.[32]

As our four countries are inflation targeters, so that the exchange rate is not their nominal anchor, these results indicate that first interventions, either isolated or first in a row, represent a signal to the markets calming their expectations and reducing their exchange rate volatility. This signaling effect happens regardless of the intervention size. In some sense, this result could be related with the signaling channel of sterilized interventions. This finding is possibly linked to the credibility of the own inflation targeting framework. Indeed, given the credibility of the monetary regime, the transparency of the intervention announces in the case of adopting an intervention rule would probably contribute to their favorable effect on volatility. This outcome is in line with other papers that defend the selective and transparent use of forex interventions under inflation targeting regimes.[33]

[32]This last result is contrary to the findings for some developed countries such as Australia. For instance, Kim et al. (2000) and Kim and Pham (2006) state that sustained and large interventions do moderate volatility.

[33]See for instance Berganza and Broto (2012) or Ostry et al. (2012).

6 Conclusions

Although many central banks actively intervene in the forex market, there is still no consensus on their efficiency to influence on the exchange rate level and to moderate its volatility. In this paper we use daily data of the USD against four Latin American currencies (namely, the CLP, COP, MXN and PEN) to analyze the impact of forex interventions of central banks on their currency returns. These four economies are among the few that publish their daily forex interventions and that have also intervened in the forex markets in the last years. We analyze if the intervention sign, which is positive or negative if there are USD purchases or sales, does make a deal to disentangle the effect of interventions on the exchange rate dynamics. We also study the role of certain intervention characteristics. Namely, we study their size and the fact or being an isolated interventions or the first intervention in a row. To this purpose, we fit several univariate GARCH models that provide new evidence on the asymmetric effects of interventions on the exchange rate volatility.

Our results indicate that forex interventions in Latin America have an asymmetric effect, specially in the conditional variance. However, there is no homogeneous pattern across countries regarding which type of interventions—positive (purchases of USD) or negative (sales of USD)—dominate the exchange rate volatility dynamics and help to stabilize it. For instance, whereas in Peru dollar purchases helped to moderate volatility, in Colombia they lead to higher volatility. Nevertheless, distinguishing the intervention sign in the model becomes a useful tool to analyze which intervention characteristics succeed to curb volatility.

Thus, once asymmetries are introduced in the conditional variance specification it is easier to disentangle which interventions, in terms of frequency and size, do impact on the exchange rate level and volatility in the desired direction. Again, it is difficult to establish regularities across the four countries but one clear pattern emerges from our results: the intervention size plays a minor role to influence on the exchange rate. That is, sizeable interventions have no greater influence on the exchange rate than small interventions. On the contrary, first in a row or isolated interventions are helpful to curb the currency volatility in the four countries. As these economies are inflation targeters, so that in principle their exchange rate is fully flexible, this result might indicate that initial or one-off interventions do send a signal to the markets, regardless the their size, which becomes useful to reduce their currency volatility. This outcome could be linked to the credibility of their inflation targeting regime.

These results are important for central banks to asses on the effect of forex interventions. However, this analysis still lacks other relevant elements such as the generalization of the model to include other characteristics of forex interventions, such as persistence, or further control variables in the level equation, such as the degree of exchange rate misalignment or a measure of carry-trade attractiveness, like the carry-to-risk, that can be relevant in the case of high yielding commodity linked currencies like ours. We leave these extensions for future research.

Appendix: Forex intervention data sources

Chile

- Source: Banco Central de Chile (http://www.bcentral.cl/estadisticas-economicas/series-indicadores/index _db.htm).

- Notes: During the sample period, consistently with its foreign exchange policy since Chile adopted an inflation target in 1999, the central bank implemented intervention rules in several occasions but only under exceptional circumstances. From April 2008 to September 2008 the central bank daily purchased 50 million USD to accumulate 8 billion USD to increase the foreign reserves under increasing uncertainty. However, this program was suspended before completion in September 2008. From March 2009 to November 2009 the Treasury sold USD on a daily basis. Finally, on January 2011 the central bank announced to buy 12 billion USD in reserves throughout 2011 through daily purchases of 50 million USD.

Colombia

- Source: Banco de la República de Colombia (http://www.banrep.gov.co/series-estadisticas/see_s_externo_2.htm#banda).

- Notes: From November 1999 to October 2009, after the inflation targeting adoption in September 1999, the authorities followed an exchange rate based rule which allowed the possibility to intervene in the forex market by auctions (put or call). The aim of these interventions was to increase or decrease the level of international reserves and to control the exchange rate volatility. Most interventions in that period consisted in auctions in put options to accumulate reserves, but the central bank also announced occasionally call options for reserve disaccumulation. To control for the exchange rate volatility, each time the COP depreciated (appreciated) more than 4% below (above) the average exchange rate of the previous 20 days, volatility auctions were held to sell put (call) options. Since then, this program has been replaced by a direct intervention mechanism consisting on the purchase of at least 20 million USD a day. Fully discretionary interventions are not included in our sample as they are not publicly available.

Mexico

- Source: Banco de Mexico (http://www.banxico.org.mx/sistema-financiero/estadisticas/mercado-cambiario/operaciones-vigentes-del-banc.html).

- Notes: From 1996 to June 2001 the Mexican authorities intervened 14 times in a discretionary way while they frequently purchased USD through put options' auctions. From May 2003 to July 2008, a significant reserve accumulation led the authorities to sell USD to the market in a preannounced volume (see Guimarães and Karacadag, 2004). From October 2008, to alleviate the depreciatory pressures and high volatility of the MXN after the onset of the crisis, Banco de Mexico performed several discretionary interventions based on extraordinary USD auctions whenever the MXN depreciated more than 2%. From March 2009, this mechanism was combined with USD auctions without a minimum price. Finally, on February 2010 it was announced a put options mechanism to build forex reserves, in a similar way to that of the period from 1996 to 2001. This last mechanism was suspended in November 2011.

Peru

- Source: Central Reserve Bank of Peru (http://estadisticas.bcrp.gob.pe/index.asp?sIdioma=1&sTitulo=OPERACIONES%20CAMBIARIAS%20BCRP%20(mill.%20US$)&sFrecuencia=D).

- Notes: The Central Reserve Bank of Peru classifies their forex operations in four broad categories (namely, over the counter purchases and sales, net swap operations, certificates of deposit in USD and operations with the public sector). These mechanisms were mixed throughout the sample period.

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Figure 1: Daily bilateral exchange rates against the dollar and forex interventions in Chile, Colombia, Mexico and Peru.

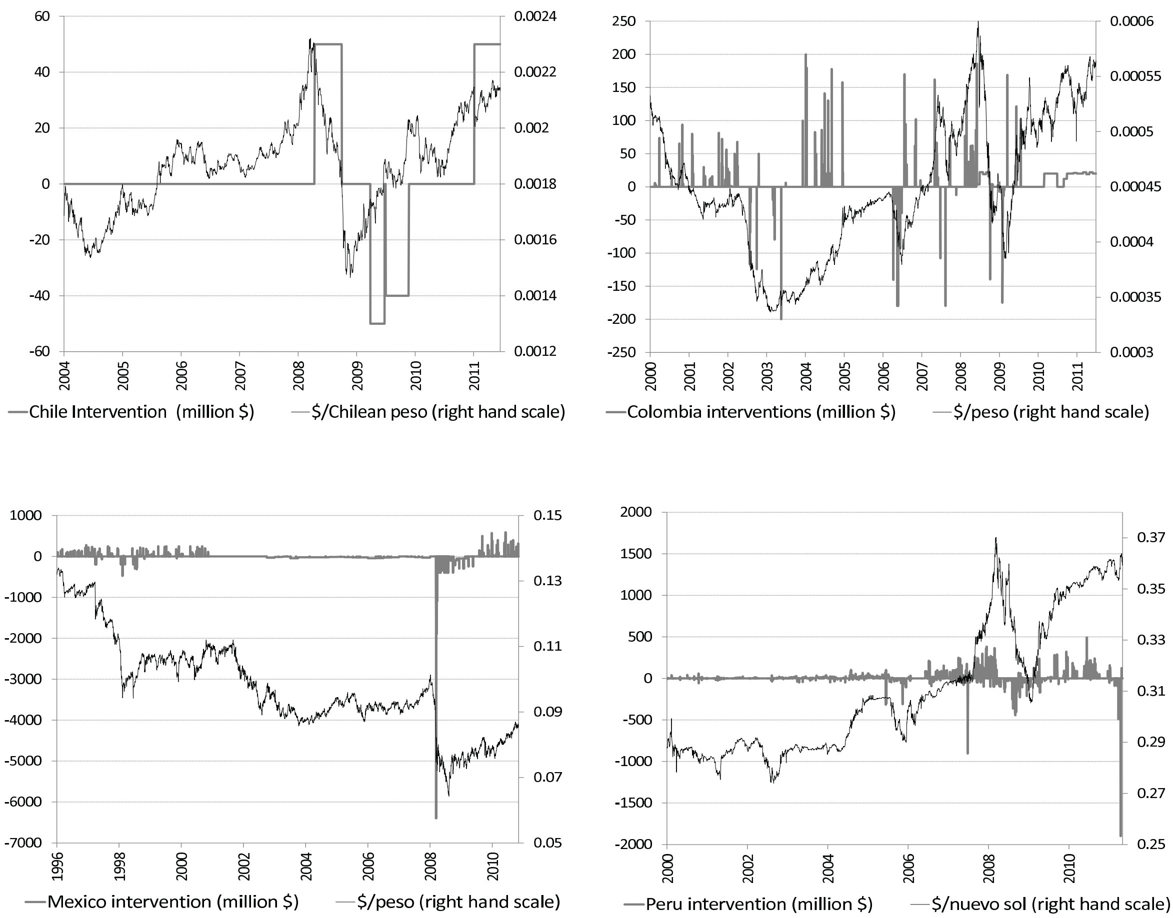

Table 1: Data description

Country	Exchange Rate Arrangement	Monetary Policy Framework	Sample period	I_t (% on total)	I_t^- (% on I_t)	I_t^+ (% on I_t)
Chile	Independently floating	Inflation targeting	01/01/2004-15/06/2011	21	41	59
Colombia	Managed floating	Inflation targeting	03/01/2000-30/06/2011	19	7	93
Mexico	Independently floating	Inflation targeting	31/07/1996-06/06/2011	42	89	11
Peru	Managed floating	Inflation targeting	01/02/2000-03/06/2011	61	34	66

Notes: Intervention data obtained from national sources. The exchange rate regime follows the de facto classification of exchange rate regimes and monetary policy frameworks of IMF (2009). Colombia and Peru have a managed floating regime with no pre-determined path for the exchange rate.

Figure 2: Daily returns of the US dollar against the Chilean peso (CLP), the Colombian peso (COP), the Mexican peso (MXN) and the Peruvian nuevo sol (PEN).

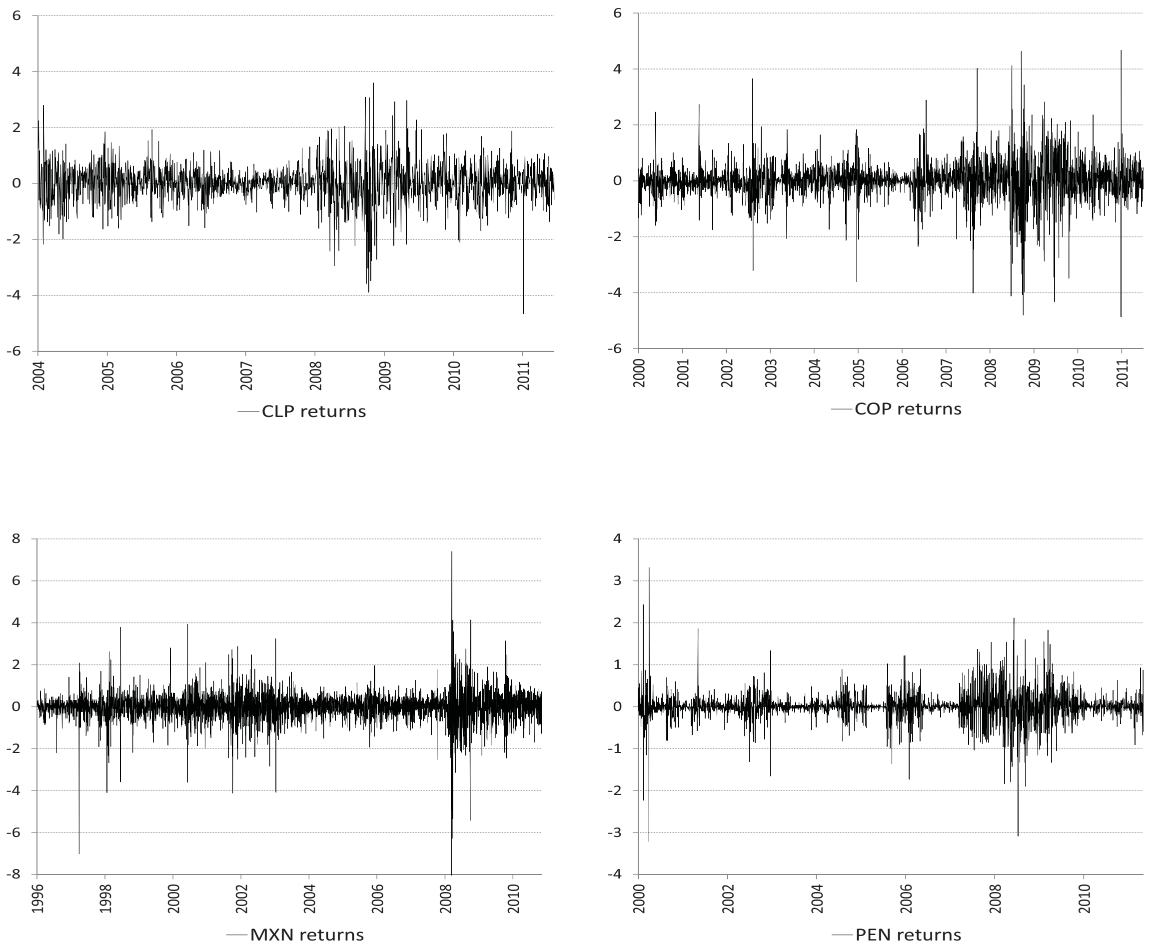

Figure 3: Rolling baseline model, equations (2) to (4); t-statistics for $\hat{\gamma}_1$. Rolling window of 1500 observations for Colombia, Mexico and Peru and 750 observations for Chile.

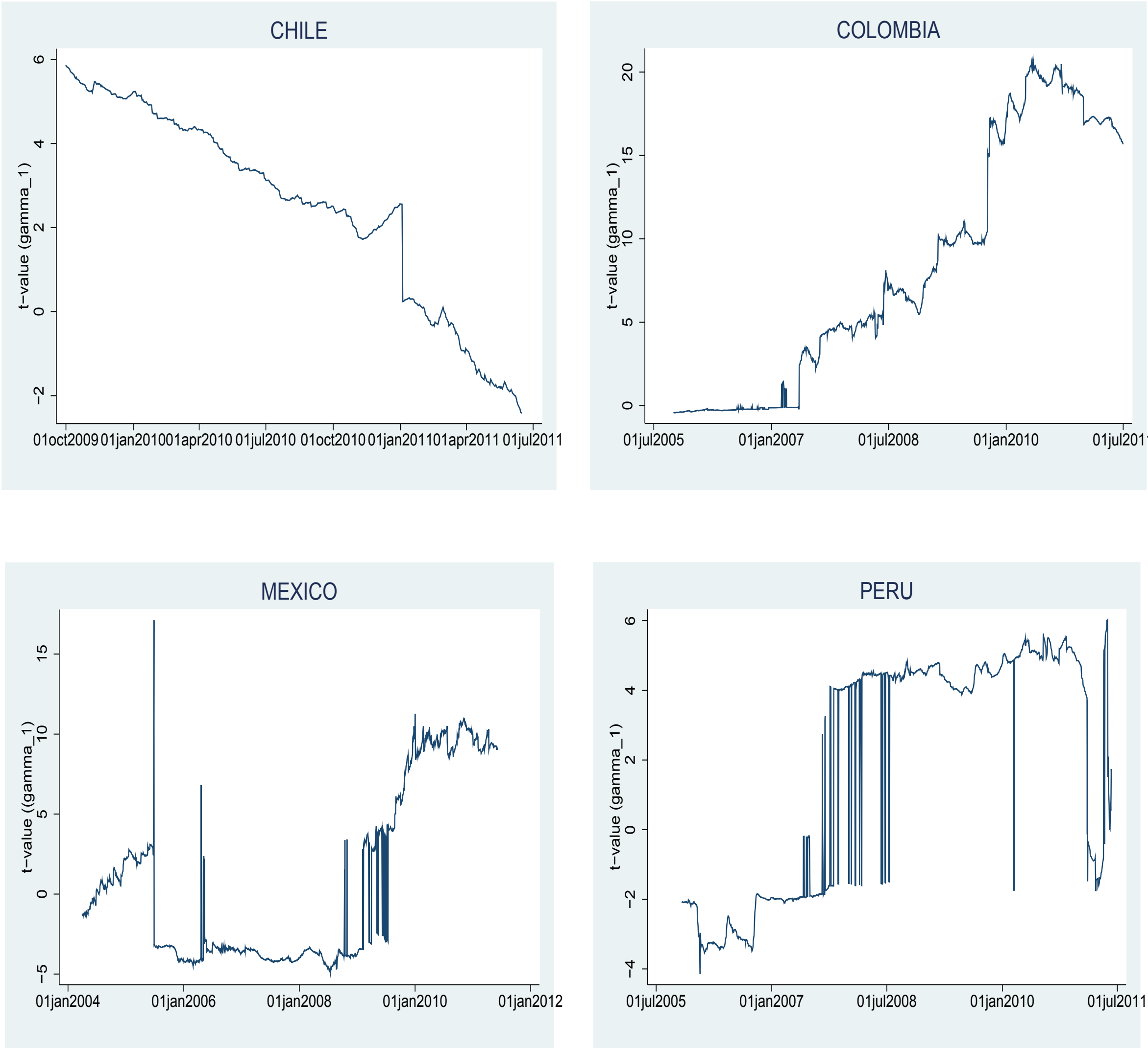

Table 2: Descriptive statistics of daily exchange rate returns and forex interventions.

	Chile				Colombia			
	r_t	I_t	I_t^-	I_t^+	r_t	I_t	I_t^-	I_t^+
Mean	0.0120	11.3647	-43.7951	50.000	0.0019	18.4288	-68.1748	24.8378
SD	0.6885	46.3264	4.8673	0	0.6899	37.9296	61.3347	26.0057
Maximum	3.5972	50.000	-40.000	50.000	4.6754	200.000	-1.000	200.000
Minimun	-4.6574	-50.000	-50.000	50.000	-4.8712	-199.900	-199.900	0.500
Skewness	-0.4300^{***}	-0.3719^{***}	-0.4965^{***}		-0.4054^{***}	-0.7768^{***}	-0.6844	4.0564^{***}
Kurtosis	7.3539^{***}	1.1577^{***}	1.2465^{***}		11.6327^{***}	15.5041^{***}	2.2286^{***}	21.6638^{***}
Observations	1944	403	166	237	2998	566	39	527
$Q(20)$	61.173^{***}				52.941^{***}			
$Q^2(20)$	953.01^{***}				1665.5^{***}			
	Mexico				**Peru**			
	r_t	I_t	I_t^-	I_t^+	r_t	I_t	I_t^-	I_t^+
Mean	-0.0111	-27.1721	-43.7217	110.1429	0.0077	11.5776	-33.2135	33.5443
SD	0.6966	187.845	188.6894	107.6463	0.3325	83.2301	105.7776	58.1132
Maximum	7.4085	592.000	-6.000	592.000	3.3218	493.5	$-9.75E-04$	493.5
Minimun	-8.7164	-6400.000	-6400.000	2.000	-3.2174	-1898.606	-1898.606	$3.7E-05$
Skewness	-1.0833^{***}	-25.0712^{***}	-27.6280^{***}	1.7874^{***}	-0.1517^{***}	-7.4751^{***}	-11.1517^{***}	2.9867^{***}
Kurtosis	22.9544^{***}	825.2344^{***}	898.2819^{***}	7.0584^{***}	18.7094^{***}	170.6581^{***}	175.6535^{***}	13.8622^{***}
Observations	3873	1627	1452	175	2958	1790	589	1201
$Q(20)$	80.344^{***}				110.77^{***}			
$Q^2(20)$	2055.5^{***}				631.77^{***}			

Notes: r_t are the exchange rate returns. Forex interventions, I_t, expressed in million USD. I_t^- stands for negative forex interventions whereas I_t^+ are positive forex interventions $Q(20)$ is the Ljung-Box Q-statistic (with 20 lags) for the exchange rate returns and $Q_2(20)$ is the Ljung-Box Q-statistic (with 20 lags) for the squared returns.

Table 3: Estimates of the baseline model for the exchange rate returns of four Latin American countries.

	Chile	**Colombia**	**Mexico**	**Peru**
β_0	0.0200	0.0090	0.0161***	0.0083
	(0.0123)	(0.0070)	(0.0077)	(0.0157)
β_1	0.0769***	0.0539**	-0.0699***	-0.1470***
	(0.0258)	(0.0198)	(0.0178)	(0.0372)
β_2	-0.0007	0.0012***	$-7.41E-05$	0.0001
	(0.0006)	(0.0005)	(0.0001)	(0.0001)
α_0	0.0148***	0.0034***	0.0202***	0.0966***
	(0.0018)	(0.0004)	(0.0017)	(0.0057)
α_1	0.1108***	0.1632***	0.2135***	0.1370***
	(0.0136)	(0.0084)	(0.0067)	(0.0183)
α_2	0.8541***	0.8425***	0.7623***	0.5641***
	(0.0149)	(0.0069)	(0.0081)	(0.0266)
γ_1	0.0002**	0.0005***	$-6.54E-05$	-0.0001***
	$(9.31E-05)$	$(8.88E-05)$	$(4.59E-05)$	$(4.22E-05)$
$LogL$	-1798.384	-2348.878	-3259.688	-1213.151
$Q(20)$	32.637**	42.025***	20.077	42.912***
$Q^2(20)$	3.3481	15.468	16.960	87.970***

Note: Estimation results of the exchange rate GARCH model:

$$
\begin{aligned}
r_t &= \beta_0 + \beta_1 r_{t-1} + \beta_2 I_{t-1} + \varepsilon_t \\
\varepsilon_t &= \varepsilon_t^{\dagger} h_t^{1/2} \\
h_t &= \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 h_{t-1} + \gamma_1 \left| I_{t-1} \right|
\end{aligned}
$$

See Tables 1 and 2 for the sample size and period of each country; Dependent variable: Exchange rate returns (log difference of US dollar / local currency) ; $LogL$ denotes the value of the log likelihood function; $Q(20)$ denotes the Ljung-Box Q-statistic (with 20 lags) for the standardized residuals; $Q_2(20)$ denotes the Ljung-Box Q-statistic (with 20 lags) for the squared standardized residuals. Standard errors in brackets; ***, **, and * refer to significance at 1%, 5% and 10% level.

Table 4: Estimates of the model with asymmetries in the conditional variance for the exchange rate returns of four Latin American countries.

	Chile	**Colombia**	**Mexico**	**Peru**
α_0	0.0142^{***}	0.0034^{***}	0.2971^{***}	0.0009^{***}
	(0.0018)	(0.0004)	(0.0164)	$(4.01E-05)$
α_1	0.1094^{***}	0.1595^{***}	0.2465^{***}	0.1812^{***}
	(0.0134)	(0.0084)	(0.0199)	(0.0092)
α_2	0.8564^{***}	0.8391^{***}	0.4394^{***}	0.7771^{***}
	(0.0147)	(0.0069)	(0.0248)	(0.0034)
γ_2	0.0003^{**}	-0.0003^{***}	-0.0008^{***}	$-6.12E-06^{*}$
	(0.0001)	$(5.78E-05)$	(0.0001)	$(4.09E-06)$
γ_3	0.0003	0.0006^{***}	-0.0010^{***}	$-1.32E-05^{***}$
	(0.0001)	$(9.12E-05)$	$(2.96E-05)$	$(8.71E-07)$
$H_0 : \gamma_2 = \gamma_3$	0.4201	0.000^{***}	0.000^{***}	0.0791^{*}
$LogL$	-1798.164	-2346.522	-3800.268	167.7634
$Q(20)$	32.460^{**}	43.874^{***}	26.146	25.949
$Q^2(20)$	3.3210	14.604	413.69^{***}	8.0412

Note: Estimation results of the exchange rate GARCH model:

$$
\begin{aligned}
r_t &= \beta_0 + \beta_1 r_{t-1} + \beta_2 I_{t-1} + \varepsilon_t \\
\varepsilon_t &= \varepsilon_t^{\dagger} h_t^{1/2} \\
h_t &= \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 h_{t-1} + \gamma_2 \left| I_{t-1}^{-} \right| + \gamma_3 I_{t-1}^{+}
\end{aligned}
$$

See Tables 1 and 2 for the sample size and period of each country; Dependent variable: Exchange rate returns (log difference of US dollar / local currency) ; $LogL$ denotes the value of the log likelihood function; $Q(20)$ denotes the Ljung-Box Q-statistic (with 20 lags) for the standardized residuals; $Q_2(20)$ denotes the Ljung-Box Q-statistic (with 20 lags) for the squared standardized residuals. Standard errors in brackets. $H_0 : \gamma_2 = \gamma_3$ indicates the p-value of the Wald type test of this linear restriction. ***, **, and * refer to significance at 1%, 5% and 10% level.

Table 5: Estimates of the baseline model for the exchange rate returns of four Latin American countries.

	Chile	**Colombia**	**Mexico**	**Peru**
β_0	0.0210	0.0072	0.0197**	0.0104***
	(0.0122)	(0.00704)	(0.0091)	(0.0032)
β_1	0.0789***	0.05571***	−0.0716***	−0.0700***
	(0.0260)	(0.0199)	(0.0183)	(0.0206)
β_2	−0.0008	0.0020***	0.0004	0.0004
	(0.0006)	(0.0017)	(0.0005)	(0.0002)
β_3	0.0212***	0.0012	0.0009**	$-2.89E-05$
	(0.0062)	(0.0021)	(0.0003)	(0.0001)
β_4		−0.0023	0.0011*	0.0004
		(0.0023)	(0.0006)	(0.0003)
α_0	0.0165***	0.0042***	0.0233***	0.0052***
	(0.0018)	(0.0004)	(0.0020)	(0.0001)
α_1	0.1233***	0.1614***	0.2219***	0.3359***
	(0.0149)	(0.0096)	(0.0074)	(0.0160)
α_2	0.8377***	0.8264***	0.7498***	0.6527***
	(0.0156)	(0.0076)	(0.0092)	(0.0068)
γ_1	0.0002***	0.0011***	−0.0001*	−0.0002***
	(0.0001)	(0.0001)	$(7.03E-05)$	$(1.42E-06)$
γ_4	−0.0035	−0.0023***	−0.0003*	$3.93E-05$
	(0.0050)	(0.0007)	(0.0002)	$(2.44E-05)$
γ_5		0.0010	0.0002*	0.0002***
		(0.0007)	(0.0001)	$(4.98E-06)$
$LogL$	−1795.734	−2337.907	−3254.456	−62.5194
$Q(20)$	32.325**	45.212***	20.019	27.053
$Q^2(20)$	3.2387	14.375	16.819	6.2967

Note: Estimation results of the exchange rate GARCH model:

$$
\begin{aligned}
r_t &= \beta_0 + \beta_1 r_{t-1} + (\beta_2 + \beta_3 FIRST_{t-1} + \beta_4 SIZE_{t-1}) I_{t-1} + \varepsilon_t \\
\varepsilon_t &= \varepsilon_t^{\dagger} h_t^{1/2} \\
h_t &= \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 h_{t-1} + (\gamma_1 + \gamma_4 FIRST_{t-1} + \gamma_5 SIZE_{t-1}) \left| I_{t-1} \right|
\end{aligned}
$$

See Tables 1 and 2 for the sample size and period of each country; Dependent variable: Exchange rate returns (log difference of US dollar / local currency) ; $LogL$ denotes the value of the log likelihood function; $Q(20)$ denotes the Ljung-Box Q-statistic (with 20 lags) for the standardized residuals; $Q_2(20)$ denotes the Ljung-Box Q-statistic (with 20 lags) for the squared standardized residuals. Standard errors in brackets. $FIRST_t$ is a dummy variable that is one if $FIRST_{t-1} = 0$ and $FIRST_t \neq 0$, and cero otherwise. $SIZE_t$ is a dummy variable that is one if $|I_t|$ is bigger than the average forex intervention. ***, **, and * refer to significance at 1%, 5% and 10% level.

Table 6: Estimates of the asymmetric model for the exchange rate returns of four Latin American countries.

	Chile	Colombia	Mexico	Peru
α_0	0.0154^{***}	0.0062^{***}	0.3857^{***}	0.0989^{***}
	(0.0018)	(0.0006)	(0.0371)	(0.0201)
α_1	0.1186^{***}	0.2041^{***}	0.0901^{***}	0.1361^{***}
	(0.0145)	(0.0109)	(0.0151)	(0.0280)
α_2	0.8453^{***}	0.7916^{***}	0.5428^{***}	0.5697^{***}
	(0.0154)	(0.0083)	(0.0418)	(0.0841)
γ_2	0.0003^{**}	0.0190^{***}	-0.0065^{***}	-0.0018^{*}
	(0.0001)	(0.0047)	(0.0006)	(0.0009)
γ_3	0.0001	0.0023^{***}	-0.0005	-0.0001
	(0.0001)	(0.0001)	(0.0046)	(0.0008)
γ_6	-0.0028	-0.0071^{*}	-0.0048^{***}	0.0002
	(0.0066)	(0.0041)	(0.0012)	(0.0003)
γ_7		-0.0124^{**}	0.0134^{***}	0.0016^{*}
		(0.0015)	(0.0017)	(0.0009)
γ_8	-0.0087^{*}	-0.0032^{***}	-0.0005	-0.0002^{***}
	(0.0092)	(0.0008)	(0.0006)	$(6.70E-05)$
γ_9		0.0008	-0.0004	$-9.93E-05$
		(0.0009)	(0.0046)	(0.0008)
$H_0: \gamma_2 = \gamma_3$	0.3921	0.0004^{***}	0.1690	0.1632
$H_0: \gamma_2 + \gamma_6 = \gamma_3 + \gamma_8$	0.6132	0.0429^{**}	0.0244^{**}	0.3192
$H_0: \gamma_2 + \gamma_7 = \gamma_3 + \gamma_9$		0.4682	0.0000^{***}	0.3064
$H_0: \gamma_2 + \gamma_6 + \gamma_7 = \gamma_3 + \gamma_8 + \gamma_9$		0.0996^{*}	0.0001^{***}	0.0918^{*}
$LogL$	-1795.320	-2346.414	-4002.785	-1208.921
$Q(20)$	32.077^{**}	44.425^{***}	18.044	39.245^{***}
$Q^2(20)$	3.1754	14.375	230.15^{***}	128.64^{***}

Note: Estimation results of the conditional variance of the exchange rate GARCH model:

$$
\begin{aligned}
r_t &= \beta_0 + \beta_1 r_{t-1} + (\beta_2 + \beta_3 FIRST_{t-1} + \beta_4 SIZE_{t-1}) I_{t-1} + \varepsilon_t \\
\varepsilon_t &= \varepsilon_t^{\dagger} h_t^{1/2} \\
h_t &= \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 h_{t-1} + \\
& \quad (\gamma_2 + \gamma_6 FIRST_{t-1} + \gamma_7 SIZE_{t-1}) \left| I_{t-1}^{-} \right| + (\gamma_3 + \gamma_8 FIRST_{t-1} + \gamma_9 SIZE_{t-1}) I_{t-1}^{+}
\end{aligned}
$$

See Tables 1 and 2 for the sample size and period of each country; Dependent variable: Exchange rate returns (log difference of US dollar / local currency) ; $LogL$ denotes the value of the log likelihood function; $Q(20)$ denotes the Ljung-Box Q-statistic (with 20 lags) for the standardized residuals; $Q_2(20)$ denotes the Ljung-Box Q-statistic (with 20 lags) for the squared standardized residuals. Standard errors in brackets. $FIRST_t$ is a dummy variable that is one if $FIRST_{t-1} = 0$ and $FIRST_t \neq 0$, and cero otherwise. $SIZE_t$ is a dummy variable that is one if $|I_t|$ is bigger than the average forex intervention. p-values of the Wald type test of four linear restrictions are also included. ***, **, and * refer to significance at 1%, 5% and 10% level.

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